U.S. ARMY CORPS OF ENGINEERS
KANSAS CITY DISTRICT

LIMITED ENERGY ENGINEERING ANALYSIS (EEAP)
STUDY OF SUMMER BOILER AT HIGH TEMPERATURE HOT WATER PLANTS
FORT LEONARD WOOD, MISSOURI
FINAL SUBMITTAL

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1.0 INTRODUCTION

This report is a study of the existing High Temperature Hot Water Distribution Systems at Fort Leonard Wood, Missouri. There are two systems with central boilers located in Buildings 1021 and 2369. The study focuses on the operation of the boilers during the summer months which is required to provide domestic hot water and sanitizing steam to various buildings. Because the boilers are operating under a reduced load condition, it may be cost effective in terms of energy conservation to implement one of the following energy conservation opportunities (ECO's):

ECO #1: Install new boilers sized to match the summer hot water loads and shutdown the central hot water plants during the summer months.

ECO #2: Install new boilers in each building and shutdown the central hot water plants during the summer months.

The study also includes an examination of the existing system as an option. The existing system is not scheduled for any major repairs with the exception fo the burner retrofit. The funding for this has already been appropriated.

2.0 EXECUTIVE SUMMARY

2.1 Based on the lowest life cycle cost of each ECO, the best method to provide domestic water heating during the summer months is the Existing System. Although the existing system will consume more energy during the course of the 25 year life cycle, this option provides the lowest life cycle cost because there is no initial investment required. Other factors that make this option favorable include:

1) The existing boilers will be retrofitted with high efficiency natural gas burners that will replace the old inefficient fuel oil burners. This will reduce the energy consumption.

2) The existing water distribution piping and the existing storage tanks in each building provide a large amount of thermal energy storage. This allows the existing boilers to be shutoff for as much as 15 hours per day. The only energy consumption during this period is from the circulating pumps.

3) The upgraded controls on the existing boilers provide modulated control which allows the burners to more closely match the heating load.

The costs and energy consumption for each option is summarized in the following table.

STUDY OF SUMMER BOILERS AT HIGH TEMPERATURE HOT WATER PLANTS

SUMMARY

ITEM (Note 1)	EXISTING SYSTEM	ECO NO. 1 CENTRAL BOILER	ECO NO. 2 DECENTRAL BOILER
LIFE CYCLE COST	$3,093,898	$3,481,481	$3,279,573
LIFE CYCLE ENERGY USAGE (MMBTU)	358,025	353,700	222,725
LIFE CYCLE ANNUAL MAINTENANCE COST	$1,589,765	$1,589,765	$ 506,967
LIFE CYCLE MAJOR CAPITAL COST	$ 73,042	$ 78,270	$ 207,744
INITIAL INVESTMENT COST	-0-	$ 412,800	$1,674,001
AVERAGE SUMMER ENERGY USAGE (MMBTU)	14,321	14,148	8,909

Note 1: All life cycle costs are net present worth values.

3.0 ENERGY CONSERVATION OPPORTUNITIES (ECO's)

3.1 Existing System:

3.1.1 PLANT 1021:

The boilers in Plant 1021 circulate water at a temperature of 323°F (average) to 19 buildings. Although there are 19 buildings on the system, only 10 have their domestic water provided by the Central System. The rest have electric water heaters. The return water temperature is approximately 303°F. There are two boilers each with a capacity of 46 million BTU per hour. During the summer when building envelope heating is not required, only one boiler is operational. A 25 HP loop water pump circulates the hot water through an underground direct buried pipe distribution system. Branch piping is connected to the loop pipe mains at each building. The branch piping terminates in the Mechanical Room of each building. In most cases, the piping is fed directly into storage type domestic hot water generators. The high temperature hot water is circulated through a tube bundle at the bottom of each storage tank. In the Mess Halls, the high temperature hot water is circulated into steam generators where 15 PSIG steam is generated. The steam is then distributed to steam kettles for cooking and heat exchangers for 180°F sanitizing water for the dishwashers.

3.1.2 PLANT 2369:

There are two boilers in the central plant that circulate 323°F (average) hot water to 47 buildings. Each boiler has a capacity of 24 million BTU per hour. During the summer, only one boiler is operational. A 25 HP pump circulates hot water through an underground direct buried pipe distribution system. Branch piping is routed to each building similar to the arrangement described above for Heat Plant 1021.

3.2 ECO #1: Install Boilers for Summer Load at Central Plants:

This opportunity would incorporate a new high temperature hot water boiler sized for the peak summer heating loads and located in the central plants. For the buildings served by central plant 1021, the boiler would have a peak capacity of 9.085 million BTU per hour. The new central boiler for the system served by central plant 2369 would have a capacity of 9.7 million BTU per hour. The retrofit would require a new circulating loop water pump, controls, natural gas piping, boiler breaching and minor architectural modifications to the existing building. A lower temperature boiler was considered in lieu of the high temperature boiler, however high temperatures are required to generate steam at the mess halls and because the heat loss through the pipe distribution system reduces the delivery temperature.

3.3 ECO #2: Install Boilers for Summer Load at Each Building:

This opportunity would include placing individual domestic hot water boilers in each mechanical room. The central high temperature hot water boilers could then be shut down during the summer months. The new boilers would be natural gas fired and would circulate heated water to the existing hot water storage tanks.

The existing heat exchanger tube bundle in the storage tanks would require replacement. A small water pump circulating water from the boiler to the storage tank would also be required. The largest boilers would need a footprint of 5'-0" x 4'-6" (approximately) and may present a space problem in some of the smaller mechanical rooms.

This ECO would require an extensive expansion on the natural gas distribution system to serve the new boilers. Electric boilers were considered, however, the cost to upgrade the electrical service to each building which would include transformer replacement is more expensive than the natural gas system.

4.0 METHODOLOGY

There are a total of 66 buildings in the combined hot water system. Most of the buildings are barracks type occupancy's, however, there are a variety of support and administrative buildings. (Refer to Section 5.4 "Field Survey Data," for building classifications.) In order to determine which energy conservation opportunity (ECO) is the best, each opportunity has been evaluated by determining the life cycle cost. The ECO with the lowest life cycle cost is the recommended ECO. In order to determine the life cycle cost, the following items must be calculated:

1) Annual Energy Consumption
2) Annual Maintenance Cost
3) One Time Capital Improvements to Equipment
4) Installation Cost

These items are then input into a computer program that totals the value of each item over the estimated 25 year life of the installed equipment.

5.0 APPENDIX

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 1
INSTALL BOILERS FOR SUMMER LOAD AT CENTRAL PLAT

SUMMARY

DEMOLITION		$ 2,000
HOT WATER BOILERS (2)		120,000
PIPE		16,000
PIPE FITTINGS		12,000
PIPE INSULATION		3,700
VALVES		15,000
STRAINERS		700
WALL OPENINGS, MISC. ARCHITECTURAL		2,000
BREACHING		8,000
PUMPS (4)		7,000
TRAINING		12,000
CONTROLS		1,000
ELECTRICAL		10,000
CONCRETE PADS		1,500
STARTUP AND CLEANUP		5,000
	SUBTOTAL	215,900
WORKER'S COMP, SS, TAXES ON LABOR (25%)		11,100
	SUBTOTAL	$227,000
OVERHEAD @ 15%		34,050
	SUBTOTAL	261,050
PROFIT @ 10%		26,105
	SUBTOTAL	287,155
CONTINGENCY @ 25%		71,788
TOTAL CONSTRUCTION COST		$358,943
ENGINEERING @ 7%		25,126
SUPERVISION, INSPECTION, ADMINISTRATION (8%)		28,715
TOTAL PROJECT COST		$412,784
	ROUNDED	$412,800

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

SUMMARY

CENTRAL PLANT 1021 - BARRACKS	$ 253,700
CENTRAL PLANT 2369 - BARRACKS "A"	294,600
CENTRAL PLANT 2369 - BARRACKS "B"	265,600
CENTRAL PLANT 2369 - GYMNASIUM	27,300
MESS HALLS	175,670
GAS DISTRIBUTION	382,780
STARTUP AND CLEANUP	40,000
TRAINING, SERVICE	16,000
TOTAL CONSTRUCTION COST FOR ECO NO. 2 -	$1,455,650
ENGINEERING @ (7%)	101,896
SUPERVISION, INSPECTION, ADMINISTRATION (8%)	116,452
TOTAL PROJECT COST	$1,673,998
(ROUNDED)	$1,674,000

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

1021 BARRACKS

DEMOLITION		$ 1,500
HOT WATER BOILER (1)		8,920
PIPE		500
PIPE FITTINGS		300
PIPE INSULATION		200
VALVES		300
STRAINER		150
PUMP (1)		450
CONTROLS		200
TUBE BUNDLE		1,500
BOILER STACK		500
MISCELLANEOUS ARCHITECTURAL		2,000
	SUBTOTAL	16,520
WORKER'S COMP, SS, TAXES ON LABOR (25%)		4,500
	SUBTOTAL	21,020
OVERHEAD @ 15%		3,153
	SUBTOTAL	24,173
PROFIT @ 10%		2,417
	SUBTOTAL	26,590
CONTINGENCY @ 25%		6,648
TOTAL CONSTRUCTION COST		$ 33,238
ASBESTOS ABATEMENT		3,000
		$ 36,238
TOTAL COST FOR ALL BARRACKS = $36,238 X 7 =		$253,666
	ROUNDED =	$253,700

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

2369 BARRACKS "A"

DEMOLITION		$ 1,500
HOT WATER BOILER (1)		2,700
PIPE		400
PIPE FITTINGS		200
PIPE INSULATION		200
VALVES		250
STRAINER		100
PUMP (1)		300
CONTROLS		200
TUBE BUNDLE		1,000
BOILER STACK		500
MISCELLANEOUS ARCHITECTURAL		2,000
	SUBTOTAL	9,350
WORKER'S COMP, SS, TAXES ON LABOR (25%)		1,173
	SUBTOTAL	10,523
OVERHEAD @ 15%		1,578
	SUBTOTAL	12,101
PROFIT @ 10%		1,210
	SUBTOTAL	13,311
CONTINGENCY @ 25%		3,328
TOTAL CONSTRUCTION COST		$ 16,639
ASBESTOS ABATEMENT		3,000
		$ 19,639
TOTAL COST FOR ALL BUILDINGS = $19,639 X 15 =		$294,585
	ROUNDED =	$294,600

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

2369 BARRACKS "B"

DEMOLITION		$ 1,500
HOT WATER BOILER (1)		4,200
PIPE		400
PIPE FITTINGS		200
PIPE INSULATION		200
VALVES		250
STRAINER		100
PIPE (1)		300
CONTROLS		200
TUBE BUNDLE		1,000
BOILER STACK		500
MISCELLANEOUS ARCHITECTURAL		2,000
	SUBTOTAL	10,850
WORKER'S COMP, SS, TAXES ON LABOR (25%)		1,250
	SUBTOTAL	12,100
OVERHEAD @ 15%		1,815
	SUBTOTAL	13,915
PROFIT @ 10%		1,391
	SUBTOTAL	15,306
CONTINGENCY @ 25%		3,827
TOTAL CONSTRUCTION COST		$ 19,133
ASBESTOS ABATEMENT		3,000
		$ 22,133
TOTAL COST FOR ALL BARRACKS = $22,133 X 12 =		$265,596
	ROUNDED =	$265,600

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

2369 GYMNASIUM

DEMOLITION		$ 1,500
HOT WATER BOILER (1)		6,060
PIPE		500
PIPE FITTINGS		300
PIPE INSULATION		200
VALVES		300
STRAINER		150
PIPE (1)		450
CONTROLS		200
TUBE BUNDLE		1,500
BOILER STACK		500
MISCELLANEOUS ARCHITECTURAL		2,000
	SUBTOTAL	13,660
WORKER'S COMP, SS, TAXES ON LABOR (25%)		1,708
	SUBTOTAL	15,368
OVERHEAD @ 15%		2,305
	SUBTOTAL	17,673
PROFIT @ 10%		1,767
	SUBTOTAL	19,440
CONTINGENCY @ 25%		4,860
TOTAL CONSTRUCTION COST		$ 24,300
ASBESTOS ABATEMENT		3,000
TOTAL COST FOR ALL GYMS		$ 27,300

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
INSTALL BOILERS FOR SUMMER LOAD AT EACH BUILDING

MESS HALLS

DEMOLITION		$ 2,000
STEAM BOILER (1)		11,000
PIPE		500
PIPE FITTINGS		300
PIPE INSULATION		200
VALVES		300
STRAINER		150
PIPE (1)		600
CONTROLS		200
TUBE BUNDLE		1,500
BOILER STACK		500
MISCELLANEOUS ARCHITECTURAL		2,000
	SUBTOTAL	19,750
WORKER'S COMP, SS, TAXES ON LABOR (25%)		2,469
	SUBTOTAL	22,219
OVERHEAD @ 15%		3,333
	SUBTOTAL	25,552
PROFIT @ 10%		2,555
	SUBTOTAL	28,107
CONTINGENCY @ 25%		7,027
TOTAL CONSTRUCTION COST		$ 35,134
ASBESTOS ABATEMENT		3,000
		$ 38,134
TOTAL COST FOR ALL MESS HALLS - $38,134 X 5 -		$175,670
	ROUNDED -	$175,670

5.1 COST ESTIMATES

ESTIMATED CONSTRUCTION COST
ECO NO. 2
GAS DISTRIBUTION SYSTEM

TRENCH AND BACKFILL, CONC. REPAIR		$ 3,800
GAS PIPE (POLYETHYLENE)		56,200
PIPE FITTINGS		28,000
VALVE PITS		3,500
ISOLATION VALVES		3,700
BYPASS REGULATORS		5,400
PRESSURE REDUCING VALVES		11,770
REGULATOR VALVES		17,800
PRESSURE RELIEF VALVES		5,400
ANODELESS PRE-BENT RISERS		1,800
LUBRICATED PLUG VALVES		6,550
BUILDING REGULATOR VALVES		17,800
GAS PIPING TO BOILERS (INSIDE BUILDING)		42,000
	SUBTOTAL	237,920
WORKER'S COMP, SS, TAXES ON LABOR (25%)		14,240
	SUBTOTAL	252,160
OVERHEAD @ 15%		37,824
	SUBTOTAL	289,984
PROFIT @ 10%		28,998
	SUBTOTAL	318,982
CONTINGENCY @ 25%		63,796
TOTAL CONSTRUCTION COST		$382,778
	ROUNDED -	$382,780

5.2 CALCULATIONS

5.2.1 LIFE CYCLE CALCULATIONS

The life cycle cost in design (LCCID, pronounced El Sid') is an economic analysis computer program tailored to the needs of the Department of Defense (DOD). It is intended to be used as a tool in evaluation and ranking design alternatives for new and existing buildings. LCCID incorporates the economic criteria of the Army, Navy and Air Force for the alternative comparisons. The criteria embodied in LCCID area:

1. Office of Management and Budget (OMB) Circular A-94, March 27, 1972.
2. Code of Federal Regulations, 10 CFR 436A, 1987 Edition (including Energy Escalation Rate Projection Updates of June 1987).
3. Architect/Engineering Instructions, (Department of the Army, March 16, 1987).
4. Department of the Navy Economic Criteria, NAVFAC PVB. P-442, "Economic Analysis Handbook," July 1980.
5. Air Force Regulation 88-15 (Draft), 16 January 1986.

The LCCID output and comparison analysis is based on the following criteria.

Date of the Study (DOS)	January 1993
Midpoint of Construction (MPC)	September 1995
Project Completion	September 1996
Study Life Cycle Duration	25 Years
Start Date of Energy and Annual Maintenance	September 1996
DOE Region for Energy Escalation	Missouri, Census Region #2
Electrical Energy Cost	$0.0466/KWH
Natural Gas Energy Cost	$5.2/MMBTU

The LCCID Program, using the above criteria, will project the cost of each alternative for the entire 25 year cycle, then reduce the total to a "Net Present Worth." The following pages are the output report from the LCCID containing the Life Cycle Cost (LCC) for each alternative.

5.2.2 PEAK LOAD CALCULATIONS

The peak loads for domestic hot water and steam were estimated from the existing design drawings obtained during the field investigation. The peak loads were used to estimate the required size of the new boilers in ECO's No. 1 and 2.

PLANT 1021:

BARRACKS BUILDINGS: Each barracks building is equipped with two (2) hot water generators with a total one hour recovery capacity of 820 GPH at 100°F rise. The required heat input to meet this load is as follows:

$$820\ GPH \times 100°F\ RISE \times \frac{8.34\ LB}{GAL} = 683,880\ BTUH$$

Assume a heat exchanger efficiency of 85%.

$$TOTAL\ LOAD = \frac{683,880\ BTUH}{85\%} = \underline{804,565\ BTUH}$$

MESS HALLS: Two (2) Generators providing a total one hour recovery of 920 GPH at 100°F rise, there is also a steam generator rated at 6360 LBS/HR for space heating and kitchen equipment:

$$920\ GPH \times 100°F\ RISE \times \frac{8.34\ LB}{GAL} = 767,280\ BTUH$$

$$DOMESTIC\ HW\ LOAD = \frac{767,280}{85\%} = \underline{902,682\ BTUH}$$

ADMIN/STORAGE, BATTALION HQ AND DISPENSARY have individual water heaters for summer loads and are not connected to the Central System.

PLANT 2369:

MESS HALLS: One steam generator with a capacity of 6360 LBS/HR, one domestic water generator, storage tank capacity = 1300 gallons.

Recovery Rate For Domestic Tank = 1300 X 75% usable = 975 GPH
Using a Usable Factor of 1.0, Recovery at 100°F AT = 975 GPH

$$DOMESTIC\ HW\ LOAD = 975\ GAL \times 100°F \times \frac{8.34\ LB}{GAL} = 813,150\ BTUH$$

$$DOMESTIC\ HW\ LOAD = \frac{813,150\ BTUH}{85\%\ EFF.} = \underline{956,647\ BTUH}$$

GYMNASIUM: Two (2) domestic hot water generators with a capacity of 500 GPH at 100°F rise (combined).

$$DOMESTIC\ HW\ DEMAND = 500\ GPH \times 100°F\ RISE \times \frac{8.34\ LB}{GAL} = 417,000\ BTUH$$

5.2.2 PEAK LOAD CALCULATIONS

PLANT 2369:

GYMNASIUM:

DOMESTIC HW LOAD = 417,000 BTUH

$$TOTAL\ DEMAND = \frac{417{,}000\ BTUH}{85\%\ EFFICIENCY} = 490{,}588\ BTUH$$

BARRACKS "A": One (1) generator at 189 GPH at 100°F rise storage capacity = 304 gallons.

$$DOMESTIC\ HW\ LOAD = 189\ GPH\ X\ 100°F\ X\ \frac{8.34\ LB}{GAL} = 157{,}626\ BTUH$$

$$TOTAL\ LOAD = \frac{157{,}626\ BTUH}{85\%\ EFFICIENCY} = 185{,}442\ BTUH$$

BARRACKS "B": One (1) generator with 340 GPH at 100°F rise, 583 gallon storage capacity.

$$DOMESTIC\ HW\ LOAD = 340\ GPH\ X\ 100°F\ X\ \frac{8.34\ LB}{GAL} = 283{,}560\ BTUH$$

$$TOTAL\ LOAD = \frac{283{,}560\ BTUH}{85\%\ EFFICIENCY} = 333{,}600\ BTUH$$

OFFICE/STORAGE, HEADQUARTERS/CLASSROOM, CHAPEL, SERVICE MODULES, PROCESSING BUILDING, PX-REC CENTER AND STORAGE UNITS all have individual domestic hot water heaters and do not require summer hot water from the Central Heat Plant in Building 2369.

5.2.2 PEAK LOAD CALCULATIONS

SUMMARY
SUMMER PEAK HEAT LOADS

HEAT PLANT	BUILDING TYPE	DOMESTIC HW (BTUH)	+	STEAM (BTUH)	X	NO. BUILDINGS	-	TOTAL LOAD (BTUH)
2369	MESS HALL	956,647	+	248,650	X	2	-	2,410,594
2369	GYMNASIUM	490,588	+	0	X	1	-	490,588
2369	BARRACKS "A"	185,442	+	0	X	15	-	2,781,630
2369	BARRACKS "B"	333,600	+	0	X	12	-	4,003,200
						SUBTOTAL	-	9,686,012
1021	BARRACKS	804,565	+	0	X	7	-	5,631,955
1021	MESS HALLS	902,682	+	248,650	X	3	-	3,453,996
						SUBTOTAL	-	9,085,951

Estimate a Usable Diversity Factor of 70%

Heat Plant 2369 Load - 9,686,012 BTUH X 70% - 6780 MBH

Heat Plant 1021 Load - 9,085,951 X 70% - 6360 MBH

5.2.3 ENERGY CALCULATIONS

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

ESTIMATED AVERAGE BOILER PLANT OUTPUT ENERGY

The following data was obtained from Boiler Logs

OVERALL SUMMER AVERAGE DAILY OUTPUT ENERGY = 61.9 MMBTU

TOTAL OUTPUT ENERGY = 61.9 MMBTU X 30 DAY X 3 MO. X 2 HEAT PLANTS

$$TOTAL\ OUTPUT\ ENERGY = 11{,}142\ \frac{MMBTU}{SUMMER}$$

ESTIMATED AVERAGE BOILER PLANT INPUT ENERGY

Boiler Plant (Buildings 1021 and 2369) consume an average of 690 and 706 gallons respectively of #2 fuel oil per day, (from Boiler Logs).

Overall Summer Average Input Energy is computed as follows:

$$PLANT\ 1021\ ENERGY = 690\ GALLONS\ X\ \frac{138{,}200BTU}{GALLON}\ X\ \frac{30DAY}{MONTH}\ X\ \frac{3MONTH}{SUMMER}$$

$$PLANT\ 1021\ ENERGY = 8582\frac{MMBTU}{SUMMER}$$

$$PLANT\ 2369\ ENERGY = 706\ GALLONS\ X\ \frac{138{,}200BTU}{GALLON}\ X\ \frac{30DAY}{MONTH}\ X\ \frac{3MONTH}{SUMMER}$$

$$PLANT\ 2369\ ENERGY = 8781\frac{MMBTU}{SUMMER}$$

$$TOTAL\ INPUT\ ENERGY = 8582 + 8781 = 17{,}363\frac{MMBTU}{SUMMER}$$

$$EXISTING\ OVERALL\ PLANT\ EFFICIENCY = \frac{OUTPUT}{INPUT} = \frac{11{,}142}{17{,}363} = \underline{64}\%$$

Heat Plant 1021 has been converted to natural gas fuel and Heat Plant 2369 is scheduled for conversion. Based on an estimated part load efficiency of 80%, the estimated input energy for the existing boilers retrofitted for natural gas is as follows:

$$INPUT\ ENERGY = \frac{OUTPUT\ ENERGY}{80\%} = \frac{11{,}142}{80\%} = 13{,}928\frac{MMBTU}{SUMMER}$$

$$ESTIMATED\ BOILER\ PLANT\ LOSSES = 13{,}928 - 11{,}142 = 2786\frac{MMBTU}{SUMMER}$$

ESTIMATED ENERGY LOSS DUE TO DISTRIBUTION SYSTEM

The energy loss due to the Distribution System is caused by the conductive heat loss from the Pipe System to the surrounding ground. The heat loss for the Pipe Distribution System can be compared by the efficiency of the insulation. Expressed as a percentage, the efficiency is defined as the ratio of the heat saved by the insulation to the heat dissipated by bare pipe.

5.2.3.1 <u>EXISTING SYSTEM ENERGY CALCULATIONS</u>

$$\frac{\textit{HEAT SAVED BY INSULATION}}{\textit{HEAT LOSS OF BARE PIPE}} \times 100 = \textit{EFFICIENCY}$$

For the existing system, the insulation efficiency is assumed to be 95%. In order to determine the heat loss for the existing insulated system, the heat loss from bare pipe must be determined. Given the following:

Average Summer Loop Water Temperature	=	323°F (1)
Ground Temperature (Summer Average)	=	66°F (2)

The temperature difference is 323°F-66°F = 257°F.
Assume 8" pipe. From Table A-1, the coefficient is 2.88.
The heat loss = 257°F X 2.88 BTU/sq. ft. - hr. - °F = 740 BTU/sq. ft. - hr.
To convert this to linear feet, the conversion factor is 2.262 (from Table A-1).
Therefore:

The heat loss per linear ft. = 740 X 2.262 = 1674 BTU/hr.-ft. (bare pipe) with an overall insulation efficiency of 95%, the existing insulation has a leakage rate of 100%-95% = 5%. For 8" pipe, the insulated pipe loss is:

Heat loss per linear ft. (insulated) = 1674 BTU/hr.-ft. X 5% = 84 BTU/hr.-ft.

Using a similar computation for all pipe sizes, the following Table can be generated:

NOTES: (1) From Boiler Logs Table A-2
(2) ASHRAE 1987 Systems and Applications

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

PIPE HEAT LOSS BY CONDUCTION
BURIED HIGH TEMPERATURE HOT WATER PIPING SYSTEM

PLANT 1021

PIPE SIZE (INCHES)	BARE PIPE HEAT LOSS (BTU/HR-FT)	INSULATED PIPE HEAT LOSS (BTU/HR-FT)	X	TOTAL PIPE LENGTH (FT)	=	TOTAL HEAT LOSS (BTU/HR)
8"	1674	84		1300		109,200
6"	1304	65		3100		201,500
4"	904	45		800		36,000
3"	717	36		260		9,360
2-1/2"	601	30		4360		130,800
2"	509	25		1100		27,500
1-1/2"	414	21		500		10,500
1"	295	15		3000		45,000
		TOTALS		14420		569,800

AVERAGE HEAT LOSS = 40 BTU/HR-FT

PLANT 2369

PIPE SIZE (INCHES)	BARE PIPE HEAT LOSS (BTU/HR-FT)	INSULATED PIPE HEAT LOSS (BTU/HR-FT)	X	TOTAL PIPE LENGTH (FT)	=	TOTAL HEAT LOSS (BTU/HR)
10"	2072	104		4700		488,800
8"	1674	84		1700		142,800
6"	1304	65		2300		149,500
3"	717	36		3341		120,276
2-1/2"	601	30		400		12,000
2"	509	25		4520		113,000
1-1/2"	414	21		3410		71,610
		TOTALS		20380		1,097,986

AVERAGE HEAT LOSS = 53.8 BTU/HR-FT

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	Checked by	Date	Sheet No. 20-A

For EEAP SUMMER BOILER STUDY

* VERIFICATION OF PIPE HEAT LOSS BY CONDUCTION USING METHODS DESCRIBED IN ASHRAE HANDBOOK: 1992 SYSTEMS AND EQUIPMENT

PERFORM THE CALCULATION ON A REPRESENTATIVE PIPE:
– SELECT 8"

GIVEN THE FOLLOWING:

R_S = THERMAL RESISTANCE OF THE SOIL (h·FT·°F/BTU)
R_{IN} = THERMAL RESISTANCE OF THE PIPE INSULATION (h·FT·°F/BTU)
R_P = THERMAL RESISTANCE OF THE PIPE WALL (h·FT·°F/BTU)
K_S = THERMAL CONDUCTIVITY OF THE SOIL (BTUH·FT·°F)
d = BURIAL DEPTH TO CENTER OF PIPE (FT.)
r_o = OUTER RADIUS OF PIPE (FT)
r_i = INSIDE RADIUS OF PIPE (FT)
r_{op} = OUTER RADIUS OF PIPE WITH INSULATION (FT)
R_T = TOTAL THERMAL RESISTANCE (h·FT·°F/BTU)
K_i = THERMAL CONDUCTIVITY OF THE PIPE INSULATION (BTUH·FT·°F)
T_F = AVERAGE FLUID TEMPERATURE (°F)
T_S = AVERAGE SOIL TEMPERATURE (°F)
K_P = THERMAL CONDUCTIVITY OF THE PIPE (BTUH·FT·°F)

ASSUME THE FOLLOWING

K_S = 0.58 (ASHRAE SYSTEMS/EQUIPMENT; pg 11.13 TABLE 2)
d = 5
r_o = $8.625" \div 2 = 4.312"/12 = 0.359$ FT. (SCH 40 STEEL)
r_i = $7.981" \div 2 = 3.99/12 = 0.332$ FT.
r_{op} = $4.312 + 2.5 = 6.812/12 = 0.567$ FT (2.5" OF INSULATION)
K_i = 0.034 (CALCIUM SILICATE @ 300°F; ASHRAE SYSTEMS; pg 11.13)
T_F = 323 °F
T_S = 66 °F
K_P = 26.2 (SCH 40 STEEL)

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	Checked by	Date	Sheet No. 20-B

For EEAP SUMMER BOILER STUDY

$$R_T = R_S + R_{IN} + R_P$$

$$d/R_{O_P} = 5'\text{-}0''/.463 = 10.79 > 4 \quad \text{(USE ASHRAE 11.13 EQN 2)}$$

$$R_S = \frac{\ln[2d/r_o]}{2\pi K_S}$$

$$R_S = \frac{\ln[2\times5/.463]}{2(3.14)(0.58)} = \underline{\underline{0.843}}$$

$$R_{IN} = \frac{\ln[r_{op}/r_o]}{2\pi K_i} = \frac{\ln[.567/.359]}{2(3.14)(0.034)} = \underline{\underline{2.14}}$$

$$R_P = \frac{\ln[r_o/r_i]}{2\pi K_p} = \frac{\ln[.359/.332]}{2(3.14)(26.2)} = \underline{\underline{.000475}}$$

$$R_T = 0.843 + 2.14 + .000475 = 2.98 \text{ h}\cdot\text{FT}\cdot{}^\circ\text{F/BTU}$$

$$\text{HEAT LOSS} = \frac{T_F - T_S}{R_T} = \frac{323-66}{2.98} = \boxed{86 \frac{\text{BTUH}}{\text{FT}}}$$

SUMMARY

THIS VALUE IS APPROXIMATELY THE SAME AS THE VALUE OF 84 $\frac{\text{BTUH}}{\text{FT}}$ PROVIDED IN THE TABLE SHOWN ON PAGE 20 OF THE REPORT. CONSIDERING THE VARIATIONS THAT ARE POSSIBLE IN ASSUMING FLUID TEMPERATURE, SOIL TEMPERATURE, CONDUCTIVITIES, ETC. AN EFFICIENCY OF 95% IS A VALID ASSUMPTION FOR ~~THERMAL~~ THE INSULATION EFFICIENCY.

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

The total summer energy consumption caused by conduction heat transfer to the ground is as follows:

PLANT 1021:

$$TOTAL\ ENERGY = 569{,}800 \frac{BTU}{HR} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times 3\ MO = 1231 \frac{MMBTU}{SUMMER}$$

PLANT 2369:

$$TOTAL\ ENERGY = 1{,}097{,}986 \frac{BTU}{HR} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times 3\ MO = 2372 \frac{MMBTU}{SUMMER}$$

$$TOTAL\ PIPE\ DISTRIBUTION\ HEAT\ LOSS = 1{,}231 + 2372 = 3603 \frac{MMBTU}{SUMMER}$$

PUMP ENERGY

Plant 2369 has three (3) main loop pumps at 25 HP each during the summer months, only one of the three pumps is in operation. In addition, there are two feedwater pumps, at 5 HP each. Only one feedwater pump operates during the summer. (Assume BHP is 90% of rated HP and feedwater pump operates 50% of the time.)

TOTAL PUMP KWH = MAIN LOOP PUMP KWH + FEEDWATER PUMP KWH

$$MAIN\ LOOP\ PUMP\ KWH = 25\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$MAIN\ LOOP\ PUMP\ KWH = 36{,}241 \frac{KWH}{YR}$$

$$FEEDWATER\ PUMP\ KWH = 5\ HP \times 90\% \times 50\% \times .7457 \times 24 \times 30 \times 3 = 3624 \frac{KWH}{YR}$$

$$TOTAL\ SUMMER\ PUMP\ KWH = 36{,}241 \frac{KWH}{YR} + 3624 \frac{KWH}{HR} = 39{,}865 \frac{KWH}{YR}$$

MESS HALLS: (BUILDING 1740 AND 1750)

$$PUMP\ KWH = 1/2\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 725 \frac{KWH}{YR} \times 2\ MESS\ HALLS = 1450 \frac{KWH}{YR}$$

BARRACKS "A": (BUILDINGS 1771, 1730, 1725, 1731, 1732, 1726, 1724, 1722, 1768, 1766, 1764, 1763, 1774, 1775, 1733)

$$PUMP\ KWH = 1/2\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 725 \frac{KWH}{YR} \times 15\ BARRACKS = 10875 \frac{KWH}{YR}$$

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

BARRACKS "B": (BUILDINGS 1767, 1773, 1776, 1734, 1723, 1735, 1728, 1729, 1720, 1769, 1761, 1765)

$$PUMP\ KWH = 3/4\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 1087 \frac{KWH}{YR} \times 12\ BARRACKS = 13044 \frac{KWH}{YR}$$

GYMNASIUM: (BUILDING 1714)

$$PUMP\ KWH = 1/4\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 362 \frac{KWH}{YR}$$

Estimated pump power consumption for all domestic water pumps at each building.

Plant 1021 has two (2) main loop pumps at 25 HP each, during the summer months only one pump operates. In addition, there are two (2) feedwater pumps at 5 HP each. Using the same assumptions as Plant 2369:

$$MAIN\ LOOP\ PUMP\ KWH = 25\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$MAIN\ LOOP\ PUMP\ KWH = 36{,}241 \frac{KWH}{YR}$$

$$FEEDWATER\ PUMP\ KWH = 5\ HP \times 90\% \times 50\% \times .7457 \times 24 \times 30 \times 3 = 3624 \frac{KWH}{YR}$$

$$TOTAL\ SUMMER\ PUMP\ KWH = 36{,}241 \frac{KWH}{YR} + 3624 \frac{KWH}{YR} = 39{,}865 \frac{KWH}{YR}$$

Estimated pump power consumption for all domestic water pumps at each building is as follows:

BARRACKS: (BUILDINGS 1012, 1013, 1014, 1015, 1016,1028,1029)

$$PUMP\ KWH = 3/4\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 1087 \frac{KWH}{YR} \times 7\ BARRACKS = 7609 \frac{KWH}{YR}$$

MESS HALLS: (BUILDINGS 1010, 1011, 1027)

$$PUMP\ KWH = 1/2\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

$$PUMP\ KWH = 725 \frac{KWH}{YR} \times 3\ MESS\ HALLS = 2175 \frac{KWH}{YR}$$

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

SUMMARY
EXISTING SYSTEM
PUMP POWER CONSUMPTION
(SUMMER USAGE ONLY)

PLANT	LOCATION	PUMP SERVICE	HP (EACH)	PUMPS OPERATING	ANNUAL KWH
1021	CENTRAL PLANT	LOOP PUMP	25	1	36,241
1021	CENTRAL PLANT	FEEDWATER	5	1	3,624
1021	BARRACKS	CIRCULATING	3/4	7	7,609
1021	MESS HALLS	CIRCULATING	1/2	3	2,175
			SUBTOTAL		49,649
2369	CENTRAL PLANT	LOOP PUMP	25	1	36,241
2369	CENTRAL PLANT	FEEDWATER	5	1	3,624
2369	BARRACKS "A"	CIRCULATING	1/2	15	10,875
2369	BARRACKS "B"	CIRCULATING	3/4	12	13,044
2369	MESS HALLS	CIRCULATING	1/2	2	1,450
2369	GYMNASIUM	CIRCULATING	1/4	1	362
			SUBTOTAL		65,596

TOTAL LOOP PYMP ENERGY = 36,241 X 2 = 72,482 KWH/YR

TOTAL FEEDWATER PUMP ENERGY = 3624 X 2 = 7248 KWH/YR

TOTAL CIRCULATING PUMP ENERGY = 7609 + 2175 + 10,875 + 13,044 +
1450 + 362 = 35,515 KWH/HR

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

ESTIMATED SUMMER DOMESTIC HOT WATER ENERGY CONSUMPTION

HEAT PLANT	BUILDING	DAILY HW ENERGY (MBH) X	TOTAL NO. BUILDINGS X	TOTAL DAYS PER MO. X	TOTAL NO. MONTHS =	TOTAL SUMMER ENERGY (MMBTU)
1021	MESS HALLS	4784	3	30	3	1292
1021	BARRACKS	3178	7	30	3	2002
					SUBTOTAL	3294
2369	MESS HALLS	5170	2	30	3	931
2369	BARRACKS "A"	736	15	30	3	994
2369	BARRACKS "B"	1318	12	30	3	1423
2369	GYMNASIUM	1324	1	20	3	79
					SUBTOTAL	3427

ESTIMATED SUMMER STEAM ENERGY CONSUMPTION
(GENERATED FROM HIGH TEMP HOT WATER)

HEAT PLANT	BUILDING	DAILY STEAM ENERGY (MBH) X	TOTAL NO. BUILDINGS X	TOTAL DAYS PER MO. X	TOTAL NO. MONTHS =	TOTAL STEAM ENERGY (MMBTU)
1021	MESS HALLS	1417	3	30	3	383
2369	MESS HALLS	1417	2	30	3	255

TOTAL DOMESTIC HOT WATER ENERGY = 3294 + 3427 = 6721 $\frac{\text{MMBTU}}{\text{SUMMER}}$

TOTAL STEAM ENERGY = 383 + 255 = 638 $\frac{\text{MMBTU}}{\text{SUMMER}}$

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER USAGE SCHEDULE
BARRACKS
PLANT 1021

HOUR	% OF MAXIMUM	GALLONS [1]
12 AM	0%	0
1 AM	0%	0
2 AM	0%	0
3 AM	0%	0
4 AM	0%	0
5 AM	50%	410
6 AM	80%	656
7 AM	50%	410
8 AM	20%	164
9 AM	10%	82
10 AM	5%	41
11 AM	5%	41
12 PM	0%	0
1 PM	0%	0
2 PM	0%	0
3 PM	0%	0
4 PM	20%	164
5 PM	30%	246
6 PM	80%	656
7 PM	30%	246
8 PM	10%	82
9 PM	5%	41
10 PM	0%	0
11 PM	0%	0
TOTAL		3239 GALLONS

$$TOTAL\ ESTIMATED\ ENERGY = \frac{3239\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 3178 \frac{MBH}{DAY}$$

NOTES: [1] BASED ON MAXIMUM CAPACITY OF 820 GPH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER AND STEAM USAGE SCHEDULE
MESS HALLS
HEAT PLANT 1021

HOUR	% OF MAXIMUM	GALLONS[1]	STEAM (BTUH)
12 AM	0%	0	0
1 AM	0%	0	0
2 AM	0%	0	0
3 AM	0%	0	0
4 AM	0%	0	0
5 AM	0%	0	0
6 AM	0%	0	0
7 AM	0%	0	0
8 AM	10%	92	24,865
9 AM	70%	644	174,055
10 AM	50%	460	124,325
11 AM	20%	184	49,730
12 PM	20%	184	49,730
1 PM	30%	276	74,595
2 PM	90%	828	223,785
3 PM	40%	92	24,865
4 PM	10%	0	0
5 PM	10%	0	0
6 PM	40%	368	99,460
7 PM	100%	920	248,650
8 PM	70%	644	174,055
9 PM	50%	184	49,730
10 PM	20%	0	0
11 PM	10%	0	0
TOTAL		4876	1,416,900*p2243Y

TOTAL ESTIMATED HOT WATER ENERGY $= \frac{4876\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 4784 \frac{MBH}{DAY}$

TOTAL ESTIMATED STEAM ENERGY - 1417 MBH/DAY

NOTES: (1) BASED ON MAXIMUM CAPACITY OF 920 GPH FOR HOT WATER
(2) BASED ON MAXIMUM STEAM CAPACITY OF 248,650 BTUH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER AND STEAM USAGE SCHEDULE
MESS HALLS
HEAT PLANT 2369

HOUR	% OF MAXIMUM	GALLONS(1)	LBS OF STEAM(2)
12 AM	0%	0	0
1 AM	0%	0	0
2 AM	0%	0	0
3 AM	0%	0	0
4 AM	0%	0	0
5 AM	0%	0	0
6 AM	0%	0	0
7 AM	0%	0	0
8 AM	10%	98	24,865
9 AM	70%	683	174,055
10 AM	50%	488	124,325
11 AM	20%	195	49,730
12 PM	20%	195	49,730
1 PM	30%	293	74,595
2 PM	90%	878	223,785
3 PM	10%	98	24,865
4 PM	0%	0	0
5 PM	0%	0	0
6 PM	40%	390	99,460
7 PM	100%	975	248,650
8 PM	70%	683	174,055
9 PM	20%	195	49,730
10 PM	0%	0	0
11 PM	0%	0	0
TOTAL		5170	1,416,900

$$\textit{TOTAL ESTIMATED HOT WATER ENERGY} = \frac{5170\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 5073 \frac{MBH}{DAY}$$

TOTAL ESTIMATED STEAM ENERGY - 1591 MBH/DAY

NOTES: (1) BASED ON MAXIMUM CAPACITY OF 975 GPH
(2) BASED ON MAXIMUM STEAM CAPACITY OF 248,650 BTUH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER USAGE SCHEDULE
BARRACKS A
PLANT 2369

HOUR	% OF MAXIMUM	GALLONS [1]
12 AM	0%	0
1 AM	0%	0
2 AM	0%	0
3 AM	0%	0
4 AM	0%	0
5 AM	50%	95
6 AM	80%	151
7 AM	50%	95
8 AM	20%	38
9 AM	10%	19
10 AM	5%	10
11 AM	5%	10
12 PM	0%	0
1 PM	0%	0
2 PM	0%	0
3 PM	0%	0
4 PM	20%	38
5 PM	30%	57
6 PM	80%	151
7 PM	30%	57
8 PM	10%	19
9 PM	5%	10
10 PM	0%	0
11 PM	0%	0
TOTAL		750

$$TOTAL\ ESTIMATED\ ENERGY = \frac{750\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 736\frac{MBH}{DAY}$$

NOTES: [1] BASED ON MAXIMUM CAPACITY OF 189 GPH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER USAGE SCHEDULE
BARRACKS B
PLANT 2369

HOUR	% OF MAXIMUM	GALLONS [1]
12 AM	0%	0
1 AM	0%	0
2 AM	0%	0
3 AM	0%	0
4 AM	0%	0
5 AM	50%	170
6 AM	80%	272
7 AM	50%	170
8 AM	20%	68
9 AM	10%	34
10 AM	5%	17
11 AM	5%	17
12 PM	0%	0
1 PM	0%	0
2 PM	0%	0
3 PM	0%	0
4 PM	20%	68
5 PM	30%	102
6 PM	80%	272
7 PM	30%	102
8 PM	10%	34
9 PM	5%	17
10 PM	0%	0
11 PM	0%	0
TOTAL		1343 GAL/DAY

$$TOTAL\ ESTIMATED\ ENERGY = \frac{1343\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 1318 \frac{MBH}{DAY}$$

NOTES: [1] BASED ON MAXIMUM CAPACITY OF 340 GPH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

DAILY DOMESTIC HOT WATER USAGE SCHEDULE
GYMNASIUM
PLANT 2369

HOUR	% OF MAXIMUM	GALLONS [1]
12 AM	0%	0
1 AM	0%	0
2 AM	0%	0
3 AM	0%	0
4 AM	0%	0
5 AM	0%	0
6 AM	0%	0
7 AM	0%	0
8 AM	0%	0
9 AM	20%	100
10 AM	20%	100
11 AM	5%	25
12 PM	0%	0
1 PM	5%	25
2 PM	5%	25
3 PM	5%	25
4 PM	50%	250
5 PM	80%	400
6 PM	50%	250
7 PM	10%	50
8 PM	10%	50
9 PM	10%	50
10 PM	0%	0
11 PM	0%	0
TOTAL		1350 GAL/DAY

$$\textit{TOTAL ESTIMATED ENERGY} = \frac{1350\ GAL}{DAY} \times 100°F \times \frac{8.34\ LB}{GAL} \times \frac{1}{85\%} = 1324\,\frac{MBH}{DAY}$$

NOTES: [1] BASED ON MAXIMUM CAPACITY OF 500 GPH

5.2.3.1 EXISTING SYSTEM ENERGY CALCULATIONS

EXISTING SYSTEM
ENERGY SUMMARY

		MMBTU
DOMESTIC HOT WATER ENERGY CONSUMPTION (PAGE 24)		6,721
STEAM GENERATION AT MESS HALLS (PAGE 24)		638
BOILER PLANT ENERGY LOSS (ESTIMATED FOR NATURAL GAS FIRED) (PAGE 18)		2,786
MISCELLANEOUS BOILER PLANT LOSSES		180
PIPE DISTRIBUTION HEAT LOSS (PAGE 21)		3,603
TOTAL ENERGY CONSUMPTION (INPUT ENERGY)	MMBTU SUMMER	13,928

ELECTRICAL ENERGY (PAGE 23)		KWH
LOOP PUMPS		72,482
FEEDWATER PUMPS		7,248
CIRCULATING PUMPS		35,515
TOTAL ELECTRICAL ENERGY CONSUMPTION	KWH SUMMER	115,245

5.2.3.2 ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANTS

The natural gas energy consumed by this option will be the same as the energy consumed by the existing boilers that have or will be retrofitted with new and efficient burners. This is because the boilers have been upgraded with new controls that allow a modulated instead of stepped firing rate. For example, at 20% load, the burner is firing at 20% capacity. The main energy savings will be through decreased pump horsepower.

The estimated pump energy can be calculated from an estimate of the new pump horsepower. The loop pump horsepower will be significantly smaller than the existing loop pump motors, however, all other pumps will remain.

HEAT PLANT 2369 DESIGN LOAD = 6,780 MBH (PAGE 17)

Using a 150°F design water temperature difference which is consistent with the original design, the total pump capacity is as follows:

TOTAL ENERGY = W X C X TD (1)
(BTUH)

WHERE: W = WEIGHT IN LBS/HR
C = SPECIFIC HEAT OF WATER AT 370°F
TD = TEMPERATURE DIFFERENCE

REARRANGING EQUATION (1)

$$W = \frac{BTU}{C \times TD}$$

$$W = \frac{6,780,000\ BTUH}{\frac{1.05\ BTU}{LB\text{-}°F} \times (370-255°F)} = \frac{56,149\ LB}{HR}$$

CONVERT MASS RATE TO GALLONS PER MINUTE

$$FLOWRATE = \frac{56,149\ LB}{HR} \times \frac{1\ GAL}{8.34\ LB} \times \frac{1\ HR}{60\ MIN} = \frac{112\ GAL}{MIN}$$

Size the new pump for 112 GPM at 115 FT of head (existing head). New pump shall be 7-1/2 HP, end suction type. (Note the new head will be less than existing, use existing head to be conservative.)

5.2.3.2 ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANTS

HEAT PLANT 1021: Design Load = 10,302 MBH (Page 17)

$$MASS\ FLOW\ RATE = \frac{6{,}360{,}000\ BTU}{\frac{1.05\ BTU}{LB \cdot °F} \times (370-255 \cdot F)} = 52{,}670 \frac{LB}{HR}$$

$$FLOW\ RATE = 52{,}670 \frac{LB}{HR} \times \frac{1\ GAL}{8.34\ LB} \times \frac{1\ HR}{60\ MIN} = \underline{105\ GPM}$$

New pump sized for 105 GPM at 115 FT head use 7-1/2 HP motor. The Existing Building circulating and feedwater pumps would be reused under this scenario, therefore the annual pump energy would remain the same. For the new pumps, the annual summer energy consumption is as follows:

PLANT 2369 AND PLANT 1021

$$MAIN\ LOOP\ PUMP\ KWH = 7\text{-}1/2\ HP \times 90\% \times \frac{.7457\ KW}{HP} \times \frac{24\ HR}{DAY} \times \frac{30\ DAY}{MO} \times \frac{3\ MO}{YR}$$

MAIN LOOP PUMP KWH = 10,872 KWH/YR (EACH PLANT)

The total pump power consumption is summarized in Table ____.

5.2.3.2 ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANTS

ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANT
PUMP POWER CONSUMPTION

PLANT	LOCATION	PUMP SERVICE	HP (EACH)	PUMPS OPERATING	ANNUAL KWH
1021	CENTRAL PLANT	LOOP PUMP	7-1/2	1	10,872
1021	CENTRAL PLANT	FEEDWATER	5	1	3,624
1021	BARRACKS	CIRCULATING	3/4	7	7,609
1021	MESS HALLS	CIRCULATING	1/2	3	2,175
			SUBTOTAL		24,280
2369	CENTRAL PLANT	LOOP PUMP	7-1/2	1	10,872
2369	CENTRAL PLANT	FEEDWATER	5	1	3,624
2369	BARRACKS "A"	CIRCULATING	1/2	15	10,875
2369	BARRACKS "B"	CIRCULATING	3/4	12	13,044
2369	MESS HALLS	CIRCULATING	1/2	2	1,450
2369	GYMNASIUM	CIRCULATING	1/4	1	362
			SUBTOTAL		40,227
TOTAL LOOP PUMPS					21,744
TOTAL FEEDWATER PUMPS					7,248
TOTAL CIRCULATING PUMPS					35,515
					64,507

5.2.3.2 ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANTS

ECO #1 - INSTALL BOILERS AT THE CENTRAL PLANTS
ENERGY SUMMARY

		MMBTU
DOMESTIC HOT WATER ENERGY CONSUMPTION		6,721
STEAM GENERATION AT MESS HALLS		638
BOILER PLANT ENERGY LOSS		2,786
PIPE DISTRIBUTION HEAT LOSS		3,603
MISCELLANEOUS PLANT LOSSES		180
TOTAL ENERGY CONSUMPTION (INPUT ENERGY)	MMBTU SUMMER	13,928

ELECTRICAL ENERGY		KWH
LOOP PUMPS		21,744
FEEDWATER PUMPS		7,248
CIRCULATING PUMPS		35,515
TOTAL ELECTRICAL ENERGY CONSUMPTION	KWH SUMMER	64,507

5.2.3.3 ECO #2 - INSTALL BOILERS AT EACH BUILDING

This option will have the best boiler efficiency of all options because small modular boiler systems have efficiencies near 85%. Small circulating pumps must be added however, to circulate hot water from the new boilers to new low temperature tube bundles in the existing storage tank. The existing building circulating pumps will remain. Another energy advantage to this ECO is that the pipe distribution and miscellaneous losses do not exist.

ESTIMATED AVERAGE OUTPUT ENERGY = 7,359 MMBTU/YR

Assume the new boilers will be on line 80% of the time with an overall efficiency of 85%.

$$ESTIMATED\ AVERAGE\ INPUT\ ENERGY = \frac{7,359}{85\%} = 8,657 \frac{MMBTU}{SUMMER}$$

BOILER PLANT ENERGY LOSS = 8,657 - 7,359 = 1,298 MMBTU/SUMMER

The estimated boiler pump energy is as follows:

For the Barracks served by Heat Plant 1021, the peak domestic water load is 804,565 BTUH. With a 30°F temperature difference, the required pump GPM is:

$$GPM = \frac{Q}{500\ X\ \Delta T} = \frac{804,565}{500\ X\ 30} = 53.6$$

ESTIMATED PUMP HEAD = 20 FT.

SELECT AN INLINE PUMP, 1750 RPM AT 3/4 HP.

Using this approach for each building and the pump energy already calculated for the circulating pumps, the table on page 37 can be generated.

The system has little or no flow (5% or 0%) during 14 hours of the day. Allowing 2 hours for tank warmup, the boiler pump could be shutdown for 12 hours per day.

THE TOTAL DAILY

$$PUMP\ ENERGY = 3/4\ HP\ X\ 90\%\ X\ \frac{12\ HOURS}{DAY}\ X\ \frac{.7457\ KW}{HP} = 6\frac{KWH}{DAY}$$

TOTAL SUMMER PUMP
ENERGY FOR EACH
BARRACKS SERVED

$$BY\ PLANT\ 1021 = 6\frac{KWH}{DAY}\ X\ \frac{30\ DAY}{MO}\ X\ \frac{3\ MO}{SUMMER} = 540\frac{KWH}{SUMMER}$$

TOTAL SUMMER

$$PUMP\ ENERGY = 540\frac{KWH}{SUMMER}\ X\ 7\ BARRACKS = 3,780\frac{KWH}{SUMMER}$$

5.2.3.3 ECO #2 - INSTALL BOILERS AT EACH BUILDING

ECO #2 - INSTALL BOILERS AT EACH BUILDING
PUMP POWER CONSUMPTION

PLANT	LOCATION	PUMP SERVICE	HP (EACH)	PUMPS OPERATING	ANNUAL KWH
1021	MESS HALL	CIRCULATING	1/2	3	2,175
1021	MESS HALL	CONDENSATE	1/3	1	482
1021	BARRACKS	BOILER	3/4	7	7,609
1021	BARRACKS	CIRCULATING	3/4	7	7,609
2369	BARRACKS "A"	BOILER	3/4	15	16,305
2369	BARRACKS "A"	CIRCULATING	1/2	15	10,875
2369	BARRACKS "B"	BOILER	3/4	12	13,044
2369	BARRACKS "B"	CIRCULATING	3/4	12	13,044
2369	MESS HALLS	CONDENSATE	1/3	2	482
2369	MESS HALLS	CIRCULATING	1/2	2	1450
2369	GYMNASIUM	BOILER	1/3	1	482
2369	GYMNASIUM	CIRCULATING	1/4	1	362

TOTAL CIRCULATING PUMPS - 35,515 KWH/YR

TOTAL BOILER PUMPS - 37,440 KWH/HR

CONDENSATE PUMP - 964 KWH/YR

5.2.3.3 ECO #2 - INSTALL BOILERS AT EACH BUILDING

ECO #2 - INSTALL BOILERS AT EACH BUILDING
ENERGY SUMMARY

		MMBTU
DOMESTIC HOT WATER ENERGY CONSUMPTION		6,721
STEAM GENERATION AT MESS HALLS		638
BOILER ENERGY LOSS		1,298
TOTAL ENERGY CONSUMPTION (INPUT ENERGY)	MMBTU SUMMER	8,657
ELECTRICAL ENERGY		KWH
CIRCULATING PUMPS		35,515
BOILER PUMPS		37,440
CONDENSATE PUMPS		964
TOTAL ELECTRICAL ENERGY	KWH SUMMER	73,919

5.2.4 MAINTENANCE DATA

The maintenance cost for each option can be separated into two (2) categories. The first category includes scheduled periodic maintenance items and minor repair items which occur on a fairly regular basis.

The second category involves those items that occur once during the life cycle of the option. These costs include major repair and remodel costs such as a boiler replacement.

The fort is under contract with the Harbert Corporation which is responsible for all maintenance at the fort. Harbert maintains records of both scheduled and unscheduled maintenance.

The following information was obtained through interviews with representatives of Harbert concerning the maintenance of the Central Steam System. The remaining maintenance data is estimated based on projected costs.

PERIODIC MAINTENANCE (SUMMER MONTHS)

ITEM	DESCRIPTION	LABOR HOURS	LABOR RATE	MATERIAL COST	TOTAL COST
BOILER PLANT 1021	OPERATOR (3 MONTHS)	2160	$17.3/HR	---	$37,368
BOILER PLANT 1021	CHEMICALS, CALIBRATION, MINOR REPAIRS	440	$17.3/HR	$15,470	$24,812
BOILER PLANT 1021	PUMPS, CHECK SEALS	2	$17.3/HR	---	$ 35
BOILER PLANT 2369	OPERATOR (3 MONTHS)	2160	$17.3/HR	---	$37,368
BOILER PLANT 2369	CHEMICALS, CALIBRATION, MINOR REPAIRS	440	$17.3/HR	$15,470	$24,812
BOILER PLANT 2369	PUMPS, CHECK SEALS	2	$17.3/HR	---	$ 35
MODULAR HOT WATER BOILERS, PER BUILDING	INSPECTION, MINOR REPAIR	40		$ 300	$ 992/BUILDING
NEW SUMMER BOILER	OPERATOR$^{(2)}$	2160		---	$37,368/SYSTEM
NEW SUMMER BOILER	CHEMICALS, CALIBRATION, MINOR REPAIRS	440		$15,470	$24,812/SYSTEM
NEW SUMMER BOILER	PUMPS, CHECK SEALS	2		---	$ 35/SYSTEM

NOTE: (2) Estimated 1/3 total operator time compared to existing boilers due to smaller, simpler type boiler.

NON-RECURRING MAINTENANCE

ITEM	DESCRIPTION	LABOR HOURS	LABOR RATE	MATERIAL COST [1]	TOTAL COST	OCCURRENCE DATE
BOILER PLANT 1021	TUBE REPAIR	80	$17.3/HR	$ 2,000	$ 3,384	10
BOILER PLANT 1021	OVERHAUL BOILER	--	---	---	$80,000	15
BOILER PLANT 2369	TUBE REPAIR	80	$17.3/HR	$ 2,000	$ 3,384	10
BOILER PLANT 2369	OVERHAUL BOILER	--	$17.3/HR	---	$80,000	15
MODULAR HOT WATER BOILERS, PER BUILDING	REPLACE BOILER	160	$17.3/HR	$ 8,000	$10,768	15 (PER BUILDING)
NEW SUMMER BOILER HW BOILER	TUBE REPAIR	80	$17.3/HR	$ 2,000	$ 3,384	20

5.2.4 MAINTENANCE DATA

PERIODIC MAINTENANCE
(SUMMER RECURRING)

EXISTING SYSTEM	TOTAL SUMMER COST
BOILER PLANT 1021 - OPERATOR	$ 37,368
BOILER PLANT 1021 - CHEMICALS, CALIBRATION	24,812
BOILER PLANT 1021 - PUMPS	35
BOILER PLANT 2369 - OPERATOR	37,368
BOILER PLANT 2369 - CHEMICALS, CALIBRATION	24,812
BOILER PLANT 2369 - PUMPS	35
TOTAL	$124,430

SUMMER BOILER SYSTEM - ECO #1	
BOILER PLANT 1021 - OPERATOR	$ 37,368
BOILER PLANT 1021 - CHEMICALS, CALIBRATION	24,812
BOILER PLANT 1021 - PUMPS	35
BOILER PLANT 2369 - OPERATOR	37,368
BOILER PLANT 2369 - CHEMICALS, CALIBRATION	24,812
BOILER PLANT 2369 - PUMPS	35
TOTAL	$124,430

DECENTRALIZED BOILER SYSTEM - ECO #2

BOILER INSPECTION/REPAIRS: $992 X 40 BUILDINGS $ 39,680

5.2.4 MAINTENANCE DATA

NON-RECURRING MAINTENANCE

EXISTING SYSTEM	AMOUNT	YEAR
BOILER PLANT 1021 - TUBE REPAIR	$ 3,384	10
BOILER PLANT 1021 - OVERHAUL BOILER	80,000	15
BOILER PLANT 2369 - TUBE REPAIR	3,384	10
BOILER PLANT 2369 - OVERHAUL BOILER	80,000	15
SUMMER BOILER SYSTEM - ECO #1		
TUBE REPAIR (3,384 X 2 BOILERS)	$ 6,768	20
OVERHAUL BOILER (30,000 X 2)	60,000	15
DECENTRALIZED BOILER SYSTEM - ECO #2		
REPLACE BOILERS: $15,000/BUILDING X 40 BUILDINGS	$600,000	20

5.3 BOILER INFORMATION

BUILDING 1021

BOILER NO.	1	2
MANUFACTURER	FLO-KONTROL	FLO-KONTROL
TYPE	WATER TUBE	WATER TUBE
YEAR BUILT	1969	1969
YEAR INSTALLED	1969	1969
FIRING EQUIPMENT	AUTO	AUTO
FUEL	NO. 6 OIL	NO. 6 OIL
DESIGN PRESSURE	500 PSIG	500 PSIG
SERIAL NO.	186	187
OUTPUT BTUH	46 MILLION BTUH	46 MILLION BTUH

BUILDING 2369

BOILER NO.	1	2
MANUFACTURER	INTERNATIONAL	INTERNATIONAL
TYPE	WATER TUBE	WATER TUBE
YEAR BUILT	1976	1976
YEAR INSTALLED	1976	1976
DESIGN PRESSURE	500 PSIG	500 PSIG
FIRING EQUIPMENT	AUTO	AUTO
FUEL	NO. 6 OIL	NO. 6 OIL
SERIAL NO.	14680	14680
OUTPUT BTUH	24 MILLION BTUH	24 MILLION BTUH

5.3.1 SUMMER BOILER LOG DATA

6/01/92	"ON" HOURS	HOURS	ENT/LVG WATER TEMP	TOTAL MMBTU[1]
	4PM-9PM	5	340/370	30.5
	3AM-8AM	5	340/370	30.5
			TOTAL	61
6/30/92	4AM-10AM	6	330/350	24.4
	4PM-11PM	7	330/350	28.4
			TOTAL	52.8
7/30/92	7AM-2PM	7	350/370	28.4
	5PM-2AM	9	340/360	36.5
			TOTAL	64.9
8/31/92	6AM-12PM	7	350/370	28.4
	8PM-10PM	2	350/370	8.1
	10PM-2AM	4	350/370	16.2
	2AM-6AM	4	350/370	16.2
			TOTAL	68.9

OVERALL DAILY AVERAGE = 61.9 MMBTU

NOTE: [1] TOTAL MMBTU IS CALCULATED AS FOLLOWS:

ENERGY = GPM X 500 X TEMP. DIFF.

FOR 4PM-9PM ON 6/1/92:
ENERGY = (406 GPM) X 500 X (370-340) X 5 HOURS
ENERGY = 30.5 MMBTU

5.3.2 SUMMER BOILER LOG DATA

DATE	SCHEDULE	STATUS	HOURS	ENTERING WATER °F	LEAVING WATER °F	DEGREE HOURS[1]
6/01/92	8AM-4PM	OFF	8	270	290	2240
	4PM-9PM	ON	5	340	370	1775
	9PM-3AM	OFF	6	290	290	1740
	3AM-8AM	ON	5	340	370	1775
	TOTAL		24			7530
	AVG. TEMP - 7530 + 24 - 314°F					
6/30/92	11AM-4AM	OFF	5	270	290	1400
	4AM-10AM	ON	6	330	350	2040
	10AM-4PM	OFF	6	280	300	1740
	4PM-11PM	ON	7	330	350	2380
	TOTAL/AVG.		24	293	313	7560
	AVG. TEMP - 7560 + 24 - 315°F					
7/30/92	2AM-7AM	OFF	5	250	270	1300
	7AM-2PM	ON	7	350	370	2520
	2PM-5PM	OFF	3	270	290	840
	5PM-2AM	ON	9	340	360	3150
	TOTAL/AVG.		24	303	322	7810
	AVG. TEMP - 7810 + 24 - 325°F					
8/31/92	6AM-12PM	ON	7	350	370	2520
	12PM-4PM	OFF	4	270	290	1120
	4PM-7PM	OFF	3	270	290	840
	8PM-10PM	ON	2	350	370	720
	10PM-2AM	ON	4	350	370	1440
	2AM-6AM	ON	4	350	370	1440
	TOTAL/AVG.		24	323		8080
	AVG. TEMP - 8080 + 24 - 337					

OVERALL SUMMER AVG. TEMP - 323°F

TOTAL HOURS OF OPERATION - 56 HOURS

NOTE: [1] DEGREE-HOURS IS FOUND BY AVERAGING THE ENTERING AND LEAVING WATER TEMP. THEN MULTIPLYING BY THE HOURS.

5.4 FIELD SURVEY DATA

The following information was obtained from existing plans and verified at each representative building in each group. The field survey occurred from September 21 through September 25, 1992. The buildings are classified as follows:

5.4.1 SYSTEM SERVED BY HEAT PLANT IN BUILDING 2369

TYPE OF BUILDING	BUILDING NO.	TOTAL BUILDINGS
Offices and Storage	1706, 1707, 1701, 1702	4
Headquarters and Classrooms	1703, 1704	2
Gymnasium	1714	1
PX, Recreation Center	1711	1
Plan "A: Barracks	1722, 1724, 1725, 1726, 1730, 1731, 1732, 1733, 1763, 1764, 1766, 1768, 1771, 1774, 1775,	15
Plan "B" Barracks	1720, 1723, 1728, 1729, 1734, 1735, 1761, 1765, 1767, 1769, 1773, 1776	12
Service Modules	1721, 1727, 1730, 1731, 1760, 1770, 1772	7
Processing	1705	1
Storage	1700	1
Chapel	1712	1
Mess Halls	1740, 1750	2
		TOTAL 47

5.4.2 SYSTEM SERVED BY HEAT PLANT IN BUILDING 1021

TYPE OF BUILDING	BUILDING NO.	TOTAL BUILDINGS
Barracks	1012, 1013, 1014, 1015, 1016, 1028, 1029	7
Mess Halls	1010, 1011, 1027	3
Administration/Storage	1006, 1007, 1025	3
Battalion Headquarters	1008, 1009, 1022, 1023	4
Dispensary	1018, 1026	2
		TOTAL 19

5.4 FIELD SURVEY DATA

PLANT 2369	OFFICES, STORAGE 1701, 1702, 1706, 1707	DOMESTIC OIL FIRED WATER HEATER, NO HEAT EXCHANGER FOR DOMESTIC HTHW IS USED FOR SPACE HEAT ONLY, 81 GAL. CAPACITY, ELECTRIC, 6KW ELEMENT, 240V/1Ø. RECOVERY @ 40°F-140°F IS 46 GPH. SPACE HW CONVERTOR: 6.13 GPM (TUBE SIDE 350°F-225°F) SHELL SIDE @ 36.5 GPM (180°F-200°F), 17.4 SQ.FT. SURFACE AREA DOMESTIC PUMP 5 GPM @ 17 FT. TWO (2) SPACE HEAT PUMPS, 1 FOR UNIT HEAT AND AHU'S, THE OTHER FAN AHU AND FAN COILS. #3 IS SUMMER/ WINTER CHANGEOVER WITH CHS LOOP.
PLANT 2369	HEADQUARTERS/CLASSROOMS 1703, 1704	DOMESTIC WATER HEATER, 40 GAL. CAPACITY 5000 IN ELECTRIC ELEMENT 240V/1Ø, 20 GPH @ 100°F RISE. HW CONVERTER 36.8 GPM (180°F-200°F) HW IN AHU'S AND UNIT HEATERS. MAIN PUMP (CW) @ 2 HP, AU CIRC. PUMP @ 3/4 HP. DHW PUMP @ GPM, 11' HEAD.
PLANT 2369	GYM: 1714	STEAM GENERATOR: 2870 #/HR, 10 PSIG 36"ØX108", EWT/LWT = 350°/260°, 74 GPM. DOMESTIC HW (2 UNITS) GENERATOR, 600 GAL, 500 GPH @ 100° RISE 48"ØX64"(EA) EWT/LWT = 350°/ 225°F,, AHU COILS ARE STEAM, REHEAT COILS ARE STEAM, UH COILS ALSO. CHW PUMP 36 GPM, 35' HEAD 65% EFF. HW CIRC. PUMP 3 GPM @ 5 FT.
PLANT 2369	PX-REC CENTER 1711	DOMESTIC WATER HEATER, 40 GAL STORAGE, 6000 WATTS 240/1Ø, 24 GPM @ 100°F RISE. HW CONVERTOR 39 GPM, 23' (180°F-200°F). DOMESTIC PUMP 6 GPM @ 12' HEAD, NO STEAM.
PLANT 2369	BARRACKS PLAN "A"	HOT WATER GENERATOR, 304 GAL. STORAGE, 189 GPH @ 100°F, 30" X 108". HW CONVERTOR 29.14 GPM (180°F-200°F) FAN COILS USE HW, NO STEAM, PUMP @ 16' @ 8 GPM (DOMESTIC) MAIN PUMP @ 102 GPM AND 50' HEAD.
PLANT 2369	BARRACKS PLAN "B"	HOT WATER GENERATOR, 583 GAL. STORAGE 340 GPH @ 100°F, 42"ØX 108". HW CONVERTOR 56 GPM, (180°F-200°F) FAN COILS USE HW, NO STEAM, PUMP @ 198 GPM AND 69' HEAD.

5.4 FIELD SURVEY DATA

PLANT 2369	SERVICE MODULES	DOMESTIC WATER HEATER, 15 GAL., 1250 WATTS, 5 GPH @ 100°F RISE. HW CONVERTOR 7.3 GPM (180°F-200°F) HW PUMP 24 GPM @ 30' HEAD. AHU'S, RADIATORS, UNIT HEATERS ALL USE HW, NO STEAM.
PLANT 2369	PROCESSING BUILDING, 1705	DOMESTIC WATER HEATER, 30 GAL., 15 GPM @ 100°F ELECTRIC UNIT. HW CIRC. PUMP 32 GPM @ 40' HEAD 3/4 HP, HW GENERATOR 30.7 GPM (180°F-200°F) 294,400 BTUH TUBE SIDE: 5.1 GPM (350°F-225°F).
PLANT 2369	STORAGE 1700	ELECTRIC UNIT HEATERS, NO HW OR STEAM.
PLANT 2369	CHAPEL: 1712 300 SEAT	HW CONVERTOR: 58.6 GPM @ (190°F-170°F) 585,516 BTUH, 9' PD. AHU'S AND FAN COILS HAVE HW COILS. DOMESTIC WH: 50 GAL. CAPACITY 37 GPH RECOVERY @ 100°F RISE 208/3Ø ELECTRIC, 9000 W DHW CIRC. PUMP 1/6 HP, 120V/1Ø. TWO (2) MAIN PUMPS 110 GPM @ 35' HEAD, 208/3Ø, 2200 W (EA) MAY NOT BE CORRECT AS SHOWN ON DWG'S.
PLANT 2369	MESS HALL: 1740, 1750 (1986 RENOVATION)	STEAM GENERATOR: EWT - 350, LWT - 260, PRESSURE - 10 PSIG, GPM - 167, STEAM - 6360 #/HR HW GENERATOR: GPM DOMESTIC - 16.7 GPM HTHW - 17.5, EWT/LWT - 350/225, DOMESTIC - 40/140°F STORAGE TANK CAPACITY - 1300 GAL. STEAM GENERATOR PROVIDES STEAM TO PERIMETER CONVECTORS, AHU'S, UNIT HEATERS AND H & V UNITS. PUMPS: HW CIRC. 1/2 HP, TWO (2) STEAM COOKERS, 3/4" SUPPLY.
PLANT 1021	BARRACKS 1012-	HOT WATER GENERATOR SERVES 4 ZONES HW CONVERTORS FOR SPACE HEAT. EACH CONVERTOR HAS ITS OWN PUMP. 3 PUMPS ARE DUAL TEMP, THE 4TH IS HW ONLY. SERVES FAN COILS AND RADIATORS. HOT WATER GENERATORS FOR DOMESTIC WATER, 2 @ 54" X 84", 830 GAL. EACH 820 GPH @ 100°F RISE, 183 GPM COLD WATER MAKE-UP (50#).

5.4 FIELD SURVEY DATA

PLANT 1021	MESS HALLS 1010-1011	DOMESTIC HW GENERATORS (2) @ 500 GAL. EACH 920 GPH @ 100°F RISE 42" X 84"(EA). PUMP @ 7 GPM AND 10.4 FT. HW CONVERTOR 40 GPM @ (180°-200°) EWT/LWT - 380/240 ON TUBE SIDE. STEAM GENERATOR FOR KITCHEN EQUIPMENT (NO SCHEDULE).
PLANT 1021	ADMIN, STORAGE 1006, 1007, 1025	HW CONVERTOR, OUTPUT - 520 MBH 52 GPM (200°F-180°F) HW FINNED TUBES. ELECTRIC DOMESTIC WATER HEATER 1/6 HP CIRC. PUMP, HEATER @ 208V/1Ø 60 A BREAKER, 1" HWS/HWR, 80 GAL. CAPACITY TWO ELEMENTS @ 4500 W EACH.
PLANT 1021	BAT HQ, CLASS 1008, 1009, 1022, 1023	HW CONVERTOR, 30 GPM @ (180°F-200°F) ONE UNIT SERVES AHU AND FINNED TUBE UNITS, ELECTRIC WATER HEATER 30 GAL. CAPACITY, 2500 WATTS, (2) ELEMENTS 208/1Ø, 5KW TOTAL.
PLANT 1021	DISPENSARY 1018	HW CONVERTOR: 19 GPM @ (200°F-180°F) 189 MBH 28' HEAD ON PUMP, ALL HW, NO STEAM. ELECTRIC WATER HEATER 38 GPH @ 100°F 52 GAL. STORAGE 10KW TOTAL 208/1Ø.

5.5 CLARIFICATIONS AND ASSUMPTIONS

1) This study is based on the premise that the boilers in buildings 2369 and 1021 (Central Plant) have been converted to natural gas.

2) Pump BHP is approximately 90% of rated HP.

3) Feedwater pumps operate 50% of the time.

4) The summer months consist of the months of June, July and August. During this time, only one HTHW Boiler is in operation.

5) Energy consumption was estimated using the following factors:

   ELECTRICAL ENERGY = $0.0466/KWH (FLAT RATE)
   NATURAL GAS = $5.2/MMBTU

   The electric rate is flat with no adjustments made for demand charges.

6) The life cycle for all alternatives is 25 years.

7) The efficiency of the existing direct buried pipe is 95%.

8) Average circulating water temperature is the average obtained from the boiler logs.

5.6 NOMENCLATURE

MMBTU/HR	MILLION BTU PER HOUR
DX	DIRECT EXPANSION
LCCID	LIFE CYCLE COST IN DESIGN
PW	PRESENT WORTH
KWH	KILOWATT HOURS
CFH	CUBIC FEET PER HOUR OF NATURAL GAS
MCF	CFH X 1000
MBH	THOUSAND BTU PER HOUR
BOD	BUILDING OCCUPANCY DATE
M&R	MAINTENANCE AND REPAIR
HTHW	HIGH TEMPERATURE HOT WATER